Evolving from Legacy Protocols: Transitioning from RIP and EIGRP to OSPF, IS-IS and BGP

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Abstract:
With the advent of the internet and growing complexity in the networking environment, old protocols like Routing Information Protocol (RIP) or Enhanced Interior Gateway Routing Protocol (EIGRP) pose significant bottlenecks for modern businesses and service providers. This paper provides an overview on the evolution of RIP and EIGRP, its limitations as Interior Gateway Protocols (IGPs), the benefits of moving to newer and more powerful protocols such as Open Shortest path First (OSPF), Intermediate System to Intermediate System (IS-IS) and Border Gateway Protocol (BGP). The paper further dives deep into migration strategies from legacy protocols to OSPF or ISIS. OSPF and IS-IS are considered the best enterprise routing solutions and service provider routing solutions respectively due to their scalability, performance and flexibility. In addition, it highlights the importance of BGP as an external gateway protocol to control routing across autonomous systems. The findings aims to aid network engineers in making educated decisions on protocol implementation and migration efforts.

Keywords: RIP, OSPF, IS-IS, BGP, Migration Strategies, Convergence time, Scalability.

1. Introduction

The networking industry has evolved rapidly over the last couple of decades with routing protocols facilitating efficient routing within and across networks. Among them, RIP and EIGRP were some of the most important legacy protocols in the initial phases of networking [1]. However, as networks have become more complex and bandwidth and performance requirements have increased, the drawbacks of these legacy protocols have become apparent. There are few industries where the these legacy protocols are still in use. This paper discusses the development of RIP and EIGRP and their challenges on the new advanced networks. Furthermore, it presents OSPF, IS-IS and BGP as better alternatives that will take the needs of ever increasing networks with more scalability, flexibility and efficiency. Through an analysis of these protocols, this research provides insight into the evolution of routing algorithms to meet the demands of today’s more complex, high-throughput networks and offers migration strategies for transitioning away from legacy protocols.

2. Evolution of RIP

RIP, one of the most legacy network routing protocols used today, was invented in the 1980s. It uses a distance-vector routing algorithm with hop count as the sole metric to identify the best path from source to destination. Originally architected for small scale networks, RIP’s simplicity was an attractive option for initial network deployments. However, as networks evolved and became large, the limitations of RIP began to emerge.
RIP version 1 (RIP v1), the first release of the protocol only provided support for classful routing. This lac of support for subnetting limited its usefulness in large networks that required more IP address use. In response to these limitations, RIP 2 (RIP v2) was released at the end of the 1990s. This version provided the functionality for classless inter-domain routing (CIDR), giving greater flexibility in assigning IP addresses and subnetting.

RIP's maximum hop limit of 15 did not offer any significant scalability and was not appropriate for massive networks.

```
 0                   1                   2                   3 3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Address Family Identifier (2) |        Route Tag (2)          |
+-------------------------------+-------------------------------+
|                         IP Address (4)                        |
+---------------------------------------------------------------+
|                         Subnet Mask (4)                       |
+---------------------------------------------------------------+
|                         Next Hop (4)                          |
+---------------------------------------------------------------+
|                         Metric (4)                            |
+---------------------------------------------------------------+
```

Fig 1. Routing Information protocol (RIPv2) packet header [6]

In the RIPv2 packet header, there are a number of important fields that provide routing updates [7]. Command (1 byte) determines whether it's a request or response packet. Version (1 byte) represents the protocol version and it usually is 2 for RIPv2. AFI (2 bytes) specifies the Address Family (i.e., IPv4). IP Address (4 bytes): the destination network, Metric (4 bytes): hops to the destination, up to 15 (16 unreachable). RIPv2 supports subnet masks and multicast updates, which is an enhanced functionality over RIPv1.

As RIP sends hello messages to its neighbors every 30 seconds to share routing information, regardless of changes in the network, it increases the protocol's convergence time and consumes more bandwidth [8]. When RIP v2 introduced triggered updates, they tried to correct this default protocol behavior but could not overcome the protocol's basic weakness. As network demand increased, routing protocols of a greater sophistication arose, including solutions such as OSPF and IS-IS.

3. EVOLUTION OF EIGRP

Cisco developed EIGRP in the early 1990s to solve limitation surrounding RIP. Even though EIGRP is a distance-vector protocol, it is classified as a hybrid routing protocol that has the properties of a both distance-vector protocol and a link-state protocol. This allows EIGRP to offer faster convergence and higher scalability. EIGRP uses the Diffusing Update Algorithm (DUAL) to build network paths that facilitate communication from source to destination [9]. Since DUAL maintains a topology database, it helps EIGRP achieve fast convergence by analyzing multiple possible routes to a given destination and selecting the most efficient path. This routing algorithm eliminates routing loops and enhances network performance. Additionally, EIGRP supports variable-length subnet masking (VLSM) for better IP address utilization [10].

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Header Version | Opcode        |           Checksum            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             Flags                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Acknowledgment Number                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Virtual Router ID             |   Autonomous System Number    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 2. Enhanced Internet Gateway Routing Protocol (EIGRP) packet header [11]

The EIGRP packet header contains a number of fields that play a vital role in EIGRP's convergence [12]. The Opcode (1 byte) indicates the packet type that needs to be processed, for example Update, Query or Hello. Version (1 byte) is the version of the protocol. Checksum (2 bytes) ensures data integrity. Flags (4 bytes): This field governs routing updates, such as routes initialization. Sequence Number and Acknowledgement Number (4 bytes) are used to ensure stable packet delivery. Autonomous System Number (ASN) (2 bytes) specifies the routing domain. These areas make it possible for EIGRP to enable secure, efficient and loop-free routing in complex networks.

Despite its strengths, EIGRP is a Cisco proprietary, making it less interoperable with devices that are not Cisco [13]. When companies started incorporating a multi-vendor design in their network, it became increasingly important to have vendor-independent routing protocols. This shifted the routing paradigm and lead to service providers looking for new protocols such as OSPF and IS-IS, which would provide more robust solutions.

4. CHALLENGES WITH RIP AND EIGRP

Though RIP and EIGRP were both critical routing protocols for the networking industry, there are several barriers to their use as IGPs in today's networks:

A. Lack of Scalability

RIP and EIGRP both face scalability challenges [1]. The RIP hop count of 15 severely restricts the size of networks it can operate on. Although EIGRP is scalable relative to RIP, there are limitations for larger, more advanced topologies, especially multi-vendor ones due to it being Cisco proprietary.

B. Slower Convergence Times

Slower convergence time is another challenge for both the protocols. RIP's 30 second hello timer interval may result in delayed network updates, which could result in routing loops and packet loss. While EIGRP has comparatively faster convergence time using DUAL, it's not comparable to a true link-state protocol such as OSPF and IS-IS [14].

C. No Standardization:

EIGRP is a Cisco proprietary protocol and therefore is limited to be used on Cisco's network devices [10]. The lack of standardization of EIGRP prevents organizations from adopting a multi-vendor approach and can lead to a vendor lock in and cost overruns.

D. Inefficient Bandwidth Usage

RIP and EIGRP can use quite a lot of bandwidth due their routing update mechanisms. This inefficiency is especially harmful in networks with limited bandwidths, where performance can be severely compromised.

E. Complex Network Topologies

When networks become more complex, the distance-vector protocols face several challenges [15]. The requirement for more dynamic and responsive routing processes creates the demand for protocols that have the capability to accommodate complex multi-vendor topologies.

These issues make it imperative that enterprise and service providers examine their routing approach and consider switching to advanced level protocols that can take advantage of the everchanging landscape of networking.

5. INTRODUCTION TO OSPF AND IS-IS

Open Shortest Path First (OSPF) and Intermediate System to Intermediate System (IS-IS) are two link-state routing protocols that are have gained increasing popularity in modern networks [16]. Both protocols were designed to overcome the shortcomings of distance-vector protocols, such as RIP and EIGRP, to make them more scalable, faster and more flexible.

A. Open Shortest Path First (OSPF)

OSPF was developed in the late 1980s by the Internet Engineering Task Force (IETF) to address the demands of expanding enterprise networks [17]. As a link-state protocol, OSPF has a complete view of the network topology. Each OSPF running router in the network gathers the entire view of the topology by communicating the status of its own links to all other OSPF routers in the network [18]. This enables OSPF to compute the shortest route to all destination using Dijkstra's algorithm, which leads to more efficient routing.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |     Type      |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 3. Open Shortest Path First (OSPF) packet header [19]

The OSPF packet header uses some important fields to communicate with other OSPF enabled routers [18]. Version (1 byte) specifies the OSPF protocol version, which will be 2 for OSPFv2. Type (1 byte) is used to describe the OSPF packet format, for example, Hello, Database Description or Link-State Update. Packet Length (2 bytes) is the total length of the packet size. Router ID (4 bytes) provides a unique identifier. Area ID (4 bytes) is the name of the OSPF region in which the packet is located. Data integrity Checksum (2 bytes) checks the integrity of the data. Authentication Type (2 bytes) and Authentication Data (8 bytes) secure OSPF exchanges. These fields enable fast and secure OSPF routing.

Key features of OSPF include:

- Hierarchical Design: OSPF facilitates a hierarchical network architecture with the concept of areas, providing enhanced scalability and control over routing information.
- Fast Convergence: OSPF can quickly adapt to the network topology changes, eliminating delayed routing updates to other OSPF enabled routers in the network.
- Support for CIDR and VLSM: OSPF supports classless Inter-domain routing, which provides flexibility and access to build variable-length subnets.

B. Intermediate Systems to Intermediate Systems (IS-IS)

IS-IS is another link state routing protocol, which was originally envisioned to be used in ISO networks but was later translated to be used with Internet Protocol (IP). IS-IS also maintains a holistic view of the network topology and makes path calculations and routing decisions based on Dijkstra's algorithm like OSPF. IS-IS is not based on IP, so it can be deployed across different protocols suites.

```
                                         No. of Octets
+--------------------------------+
|     INTRA-DOMAIN ROUTEING      |        1
|    PROTOCOL DISCRIMINATOR      |
+--------------------------------+
|       LENGTH INDICATOR         |        1
+--------------------------------+
|    VERSION/PROTOCOL ID EXT     |        1
+--------------------------------+
|           RESERVED             |        1
+--------------------------------+
| R | R | R |       TYPE         |        1
+--------------------------------+
|           VERSION              |        1
+--------------------------------+
|             ECO                |        1
+--------------------------------+
|           USER ECO             |        1
+--------------------------------+
|          PDU LENGTH            |        2
+--------------------------------+
|          SOURCE ID             |        7
+--------------------------------+
|         START LSP ID           |        8
+--------------------------------+
|          END LSP ID            |        8
+================================+====================
|    VARIABLE LENGTH FIELDS      |      VARIABLE
+--------------------------------+
```

Fig. 4 Intermediate Systems to Intermediate Systems (IS-IS) Level 1 PDU [20]

The IS-IS Level 1 and Level 2 headers uses some important fields to communicate with other Level 1 and Level 2 enabled IS-IS routers. The Protocol Identifier (1 byte) represents the protocol in use. Length Indicator (1 byte) sets the header length. Version/Protocol ID Extension (1 byte) is usually zero. The ID Length (1 bytes) specifies the length of system identifiers. PDU Type (1 byte) lists whether the type of packet is either Hello or Link State PDU. PDU Length (2 bytes) denotes the size of the packet. Flags and Reserved fields are also provided and the Checksum provides data integrity. These fields help IS-IS to have a fast, secure routing through networks.

Key features of IS-IS include:

- Protocol Independency: Since IS-IS is not based on Internet Protocol, it can support multiple network layer protocols that enable organizations to meet diverse networking requirements [21].
- Scalability: IS-IS scales effortlessly over larger networks and can efficiently be routed over complicated topologies.
- Ease of Implementation: IS-IS maintains fewer databases and provides a simpler configuration than OSPF, which makes it easier to implement in service provider environments.

OSPF and IS-IS provide scalability, faster convergence time, and a low cost structure, making them attractive alternatives to RIP and EIGRP.

6. WHY SHOULD ENTERPRISES AND SERVICE PROVIDERS ADOPT OSPF OR IS-IS?

There are numerous benefits for enterprises and service providers to deploy OSPF or IS-IS, some of which are as follows:

A. Scalability:

OSPF and IS-IS are built to support massive, complex networks which is ideal for organizations going through expansion. Their hierarchical structures and ability to process large routing tables makes them capable of routing in large environments.

B. Faster Convergence time

OSPF and IS-IS have a link-state nature which can lead to faster convergence times [14]. This is extremely important for network availability, minimized downtime, and delivering data packets with efficiency.

C. Support for Modern Technologies

Both protocols are also designed to address advanced networking technologies like Virtual Private Networks (VPNs), Multi-Protocol Label Switching (MPLS), and Software-Defined Networking (SDN) [22]. The support they offer for advanced capabilities also means organizations can take advantage of new technologies without being held back by old protocols.

D. Interoperability

OSPF and IS-IS, being open standards, allow devices from different manufacturers to be interoperable. This flexibility enables organizations to move towards a multi-vendor approach which mitigates vendor lock-in and promotes competition.

E. Enhanced Security Features

OSPF supports features like authentication and encryption that secures routing updates. IS-IS, while less focused on security, nonetheless offers routing information integrity mechanisms.

F. Improved Resource Utilization

OSPF and IS-IS reduce bandwidth utilization with its efficient control plane mechanisms such has routing updates.

In migrating to OSPF or IS-IS, enterprises and service providers can extend their networking performance, and position themselves better for future growth.

7. RIP TO OSPF MIGRATION

While migrating from RIP to OSPF, please follow the following best practices:

A. *Configure OSPF*

- Configure OSPF on all routers in the network, and configure appropriate OSPF areas (backbone area 0 and so on) as per the topology [23].
- Configure OSPF administrative distance higher than RIP to default to RIP routes. This is an important step as OSPF's administrative distance is lower by default. If the routes are not tagged with a higher administrative distance (over 120), routing table will mark OSPF routes as their best path.
- Configure OSPF Router IDs and enable OSPF either by adding a network statement under OSPF process or by enabling OSPF under the interface.
- Assign router IDs and configure OSPF interfaces.

B. *Redistribute RIP into OSPF (Only in special cases):*

- Configure route redistribution from RIP to OSPF on adjacent border routers during the migration. Use this step only if the organization is planning on building an OSPF topology adjacent to a RIP topology.

C. *Gradual Transition:*

- Once OSPF is up and running on the same networks, update the OSPF network statements by removing the higher AD value that was set in Step A. Verify that the route table is populated with OSPF routes. Start removing network statements one by one under the RIP process.

D. *Monitor and Verify:*

- Continuously monitor routing tables to ensure that OSPF takes over without issues. Verify connectivity between OSPF areas and external networks. Once the routing table is populated with OSPF routes, you can delete the RIP process from all the routers.

8. RIP TO IS-IS MIGRATION

When migrating from RIP to IS-IS, please use the following best practices:

A. Configure IS-IS:

- Configure IS-IS on all the routers. Make sure to configure specific links on each router as either Level-1 (similar to area 0 in OSPF) and Level-2 (for inter-area routing) [24]. Please refer to the IS-IS configuration guide to understand key differences between OSPF and IS-IS.
- Configure IS-IS administrative distance higher than RIP to default to RIP routes. This is an important step as IS-IS's administrative distance is lower by default. If the routes are not tagged with a higher administrative distance (over 120), routing table will mark IS-IS routes as their best path.

B. Redistribution (Only in special cases):

- Redistribute RIP into IS-IS on adjacent border routers during the migration phase.

C. Phased Migration:

- Once IS-IS is up and running on the same networks, update the IS-IS network statements by removing the higher AD value that was set in Step A. Verify that the route table is populated with IS-IS routes. Start removing network statements one by one under the RIP process.

D. Monitor and Verify:

- Continuously monitor routing tables to ensure that IS-IS takes over without issues. Once the routing table is populated with IS-IS routes, go ahead and delete the RIP process from all the routers.

9. EIGRP TO OSPF MIGRATION

A. Configure OSPF

- Configure OSPF on all routers in the network, and configure appropriate OSPF areas (backbone area 0 and so on) as per the topology.

- Configure OSPF Router IDs and enable OSPF either by adding a network statement under OSPF process or by enabling OSPF under the interface [25].
- Since EIGRP's administrative distance is 90, OSPF routes will not take over as OSPFs administrative distance is 110.
- Assign router IDs and configure OSPF interfaces.

B. Redistribute EIGRP into OSPF (Only in special cases):

- Configure route redistribution from EIGRP to OSPF on adjacent border routers during the migration. Use this step only if the organization is planning on building an OSPF topology adjacent to a EIGRP topology.

C. Gradual Transition:

- Once OSPF is up and running on the same networks, start removing network statements one by one under the EIGRP process. Once the EIGRP network statements are removed, the OSPF routes will be populated in the routing table.

D. Monitor and Verify:

- Continuously monitor routing tables to ensure that OSPF takes over without issues. Verify connectivity between OSPF areas and external networks [23]. Once the routing table is populated with OSPF routes, you can delete the EIGRP process from all the routers.

10. EIGRP TO IS-IS MIGRATION

When migrating from EIGRP to IS-IS, please use the following best practices:

A. Configure IS-IS:

- Configure IS-IS on all the routers. Make sure to configure specific links on each router as either Level-1 (similar to area 0 in OSPF) and Level-2 (for inter-area routing). Please refer to the IS-IS configuration guide to understand key differences between OSPF and IS-IS.
- Since EIGRP's administrative distance is 90, IS-IS routes will not take over as IS-IS's administrative distance is 115.

B. Redistribution (Only in special cases):

- Redistribute EIGRP into IS-IS on adjacent border routers during the migration phase [26].

C. Phased Migration:

- Once IS-IS is up and running on the same networks, update the IS-IS network statements by removing the higher AD value that was set in Step A. Verify that the route table is populated with IS-IS routes. Start removing network statements one by one under the EIGRP process.

D. Monitor and Verify:

- Continuously monitor routing tables to ensure that IS-IS takes over without issues. Once the routing table is populated with IS-IS routes, go ahead and delete the EIGRP process from all the routers.

11. IMPORTANCE OF BGP AS AN EXTERIOR GATEWAY PROTOCOL

As organizations grow their networks and join the wider internet, a robust external gateway protocol (EGP) is needed. The Border Gateway Protocol (BGP) is the default protocol for inter-domain routing and integral to the functioning of the worldwide internet.

BGP is path-vector-based, letting routers pass routing data to and from AS. Each AS has routing policies which enables organizations to provide fine-grained control of traffic routing. Some features of BGP are:

A. Scalability

BGP supports an enormous number of routes, which makes it suitable for web-based network topologies [27]. The fact that it has a way to process routing data across multiple AS makes it a viable solution for global routing.

B. Policy-Based Routing

BGP lets administrators set routing policies by AS path, prefix length and next hop attributes [27]. This flexibility allows organizations to deploy traffic engineering and improve network performance.

C. Loop Prevention

BGP incorporates a highly advanced loop-prevention function that preserves the integrity of the routing data and avoids routing loops that can compromise the network [28].

E. Integration with Other Protocols

BGP supports multiple layer protocols, allowing more options for companies that may require a mix of networking technologies [29].

In summary, BGP has become a fundamental part of the modern network and can be deployed in many organizations to facilitate inter-domain routing and ensure proper communication among separate systems.

12. CONCLUSION

Transition from legacy protocols such as RIP, EIGRP to the advanced routing protocols such as OSPF, IS-IS, and BGP is fundamental to a growing networking landscape. RIP and EIGRP were useful in more limited network scenarios, but they were slow in scaling, convergence and lacked interoperability.

OSPF and IS-IS provide the scalability and performance that today's enterprise networks need, and BGP handles routing between two autonomous systems across the worldwide internet. If organizations embrace these new protocols, they can boost network performance, increase resilience, and prepare for growth and technologies of the future.

Finally, networking is an evolving industry, so companies are encouraged to constantly review their routing protocols and adopt protocols that can meet the needs of the digital future. Switching to OSPF, IS-IS and BGP is recommended for any organization seeking to excel in the modern networking landscape.

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